

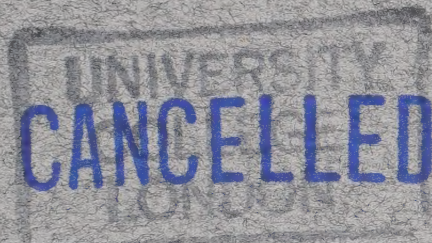
Reprinted from the American Journal of Physiology.

VOL. XXIX. — DECEMBER 1, 1911. — No. II.

THE RECEPTIVE RELAXATION OF THE STOMACH.

By W. B. CANNON AND C. W. LIEB.

[FROM THE LABORATORY OF PHYSIOLOGY IN THE HARVARD MEDICAL SCHOOL.]



C.

WELLCOME INSTITUTE LIBRARY	
Coll.	welMomeo
Coll.	perm
No	WI 300
	1911
	C22r



22500892825

THE RECEPTIVE RELAXATION OF THE STOMACH.¹

BY W. B. CANNON AND C. W. LIEB.

[*From the Laboratory of Physiology in the Harvard Medical School.*]

IN 1898 Langley described the action of inhibitory fibres for the lower end of the œsophagus and the cardiac portion of the stomach.² With moderate electrical stimulation of a vagus nerve in the neck he observed relaxation of both these regions, followed by strong contraction when stimulation ceased. The function of inhibitory impulses for the lower œsophagus had previously been described by Kronecker and Meltzer.³ They noted during repeated deglutition that the cardiac sphincter became more and more relaxed as the number of swallows increased, and that, after the passage of the swallowed material, the sphincter promptly contracted. This contraction was much more intense and lasted longer, the longer the series of swallowing movements that preceded.

The relaxation of the terminal sphincter of the œsophagus, as a peristaltic wave is driving a bolus towards it, is an excellent illustration of the general law that opposed muscles normally act, not in opposition, but in reciprocal co-operation — a law which Meltzer emphasized in this connection.⁴

That vagus innervation of the cardiac end of the stomach is similar to that of the cardiac sphincter received confirmation in an investigation by May, who found that with moderate stimulation the cardiac sac could be maintained in relaxation in some instances for sixty or

¹ The results of this investigation were reported at the meeting of the American Physiological Society in December, 1910. See the Proceedings, This journal, 1911, xxvii, p. xiii.

² LANGLEY: Journal of physiology, 1898, xxiii, p. 407.

³ KRONECKER and MELTZER: Archiv für Physiologie, 1883, Supplement-Band, p. 358.

⁴ MELTZER: Archiv für Physiologie, 1883, p. 215.

seventy seconds, and that this inhibition was followed by an augmentor effect, indicated by increased tonus and peristaltic waves of greater amplitude than normal.⁵

Since electrical stimulation of the cervical vagus affects in the same manner the lower œsophagus and the cardiac end of the stomach, it seemed probable that the act of deglutition might cause gastric relaxation, just as it causes relaxation of the cardia.

The importance of a relaxation of the stomach, especially of the large reservoir in the cardiac end, when food is swallowed, is obvious if the pressure in the active stomach is considered. Intragastric pressure has been reported in different animals and at different times as ranging from 7 to 19 cm. of water in the cardiac end, and from 25 to 162 cm. of water in the pyloric end.⁶ These pressures are produced by the tonus of the gastric musculature. This tonic contraction may be regarded, therefore, like the tonic contraction of the cardiac sphincter, as an activity capable of opposing peristalsis of the œsophagus, and in the interests of organic economy preferably obviated when the œsophagus is driving material into the stomach.

That the cardia relaxes after swallowing and remains relaxed during repeated swallowing is another condition which renders inhibition of gastric tonus desirable, for if intragastric pressure remained high, and the cardia were patulous, the contents of the stomach might be pressed in large volume up the œsophagus after each act of deglutition.

The question of a receptive relaxation of the stomach when food is swallowed was tested by making, in cats completely anæsthetized, an œsophageal fistula, and, at various times after recovery from the operation, recording the pressure changes in the stomach. Through the lower opening of the fistula a soft smooth rubber catheter was introduced, bearing on its end a thin-rubber balloon, large enough, when filled, to occupy the entire cardiac end of the stomach. Into the end of the catheter, where the balloon was fastened, a piece of glass tubing was inserted. The apparatus was arranged so that the

⁵ MAY: *Journal of physiology*, 1904, xxxi, p. 262.

⁶ See v. PFUNGEN: *Centralblatt für Physiologie*, 1887, i, pp. 220, 275; MORITZ, *Zeitschrift für Biologie*, 1895, xxxii, pp. 356-358; SICK: *Deutsches Archiv für klinische Medizin*, 1906, lxxxviii, p. 190.

glass was situated within the cardiac sphincter, and thereby resisted any pressure which that sphincter might exercise. The outer end of the tube was connected with a float recorder—a cylinder 5.5 cm. internal diameter, with a small opening at the bottom to connect the catheter, and with a cork above supporting a writing lever. The balloon, the catheter, and part of the cylinder were filled with water. The cork, which nearly fitted the cylinder, and which was prevented by three inserted pins from rubbing the glass, rose and fell with the changes in water level, and affected the lever. The relatively large area of water in the cylinder permitted the recording of volume changes in the stomach without much alteration of intragastric pressure. Usually the water level in the cylinder was not more than 3 or 4 centimetres above the cardia.

At times when the balloon was introduced the stomach was in a toneless condition, but usually a tonic state prevailed which was manifested by the supporting of a water pressure of several centimetres and the recording of rhythmic contractions. The phenomena now to be reported were studied only in cases in which tonicity was found.

When the animal, unanæsthetized, was resting quietly on the holder, and a regular record of rhythmic gastric contractions was being registered, a bit of raw beef was placed at the animal's nose. The meat was usually taken with avidity and quickly swallowed. It did not, of course, pass to the stomach, but emerged from the œsophagus at the upper fistula opening. A few seconds after the larynx rose in swallowing, intragastric pressure began to fall. As Fig. 1, which is a record of the volume changes of the balloon, shows, the drop in pressure is rapid, and is followed by only a slightly less rapid recovery of the former degree of tonus.

A record of the relaxations on a more rapidly revolving drum revealed that in some instances the drop in pressure began from two to two and five-tenths seconds, and in others from four and three-tenths to four and six-tenths seconds after the rise of the larynx. The

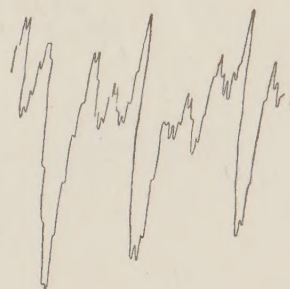


FIGURE 1.—Gastric relaxation after deglutition. The top line records changes of gastric volume; the middle line, acts of swallowing; the bottom line, time in half-minutes.

lowest point of pressure was reached from six to ten seconds — in most cases about eight seconds — after the drop began. In 1898 Cannon and Moser reported that from ten to eleven seconds were required for a solid bolus to pass through the œsophagus of the cat.⁷ It is clear from these figures that the stomach begins to relax a considerable period before the peristaltic wave has arrived at the cardia,

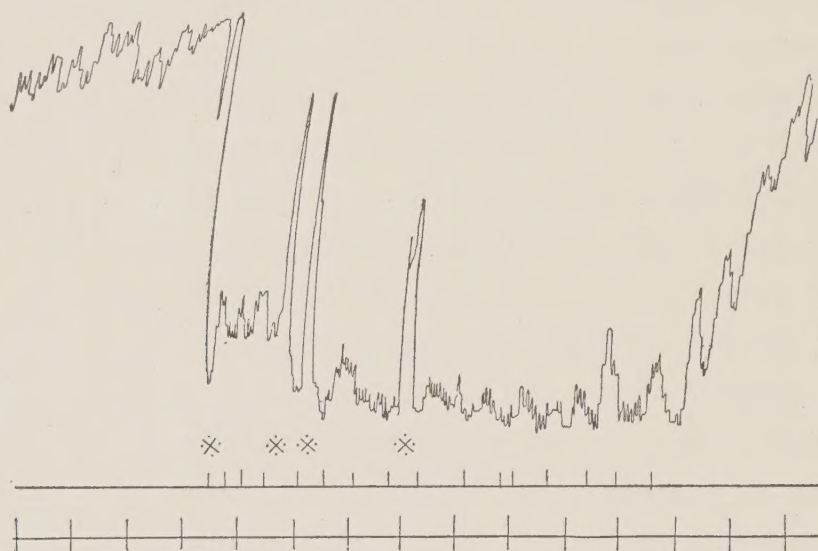


FIGURE 2. — Continued gastric relaxation with repeated deglutition. The asterisks indicate when the animal moved excitedly, causing quick changes of gastric volume. The middle line records acts of swallowing; the bottom line, time in half-minutes.

indeed while the wave may still be moving through the cervical œsophagus, and that the greatest degree of relaxation is reached approximately when the bolus would be discharged into the stomach.

The increase of gastric volume, when the pressure upon the wall ranged between 3 and 4 cm. of water, varied in one instance between 8 and 10 c.c. In other instances the increase was not so great, and in one or two cases the record showed a relaxation which would accommodate only little more than 2 c.c. of fresh content.

By substituting a glass tube for the large glass cylinder, the pressure changes in the stomach could be observed with very little change in the volume of gastric contents. Intragastric pressure was observed by this means dropping almost to zero after swallowing.

The opposition which the tonicity of the gastric musculature might offer to œsophageal peristalsis is thus seen to be abolished almost precisely when the œsophagus is discharging food into the stomach;

⁷ CANNON and MOSER: This journal, 1898, i, p. 439.

and the relaxation of the gastric wall may be so great that as much as 8 or 10 c.c. of new contents may be received without much increase in the work of œsophageal muscles. This is an admirable instance, in the autonomic system, of the unidirectional working of the law of reciprocal innervation of antagonistic muscles.

As in the cardia, so in the stomach, repeated swallowing causes continued relaxation. Fig. 2 is a record of the persistent inhibition of gastric tonus resulting from repeated swallowing of bits of meat.

When the animal became excited, the stomach was inhibited as a concomitant of the emotional condition, but recovery of the former state of tone was slower than recovery from the inhibition which follows deglutition. In Fig. 2

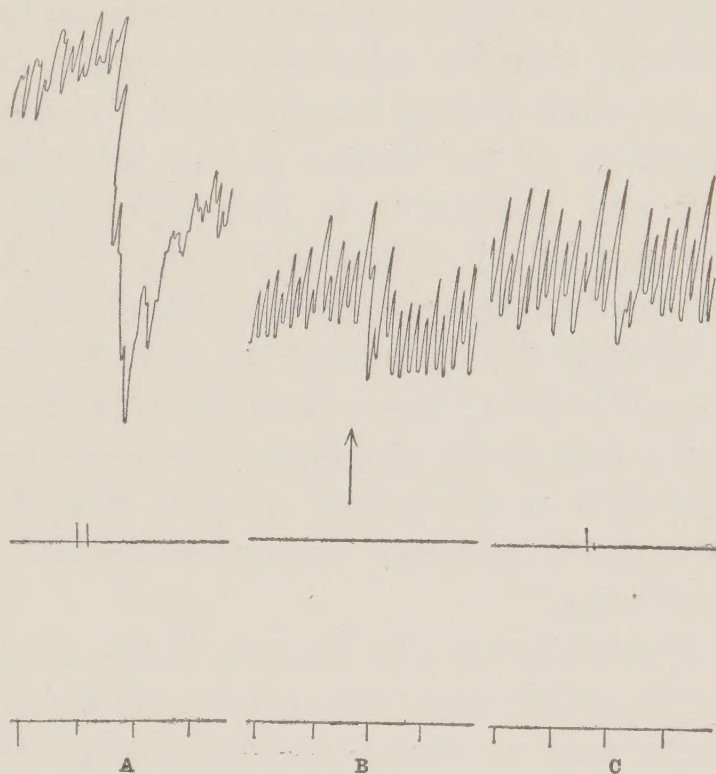


FIGURE 3. — Gastric relaxation after deglutition with right vagus cut (A), the moment of cutting the left vagus (B), and the failure of relaxation with both vagi cut (C).

the sharp changes in the record of gastric volume (above the asterisks) were due to occasional excitement and movement of the animal. The subsequent lessening of tone is notable in each instance. The continued relaxation was probably at some moments in part due to the excitement.

The inhibition of gastric contraction which attends an emotional outbreak is due to impulses discharged by way of the splanchnic nerves.⁸ The inhibition which follows deglutition is produced by way of the vagus nerves. This was proved by severing the right vagus nerve below the recurrent laryngeal in an aseptic operation, and later, after securing records of gastric relaxation after deglutition, severing the left vagus in the neck, whereupon the relaxation did not

⁸ CANNON: American journal of the medical sciences, 1909, cxxxvii, p. 485.

occur when the animal swallowed (see Fig. 3). That the relaxation normally begins a considerable time before the peristaltic wave in the œsophagus arrives at the stomach, indicates that the vagus impulses anticipate the œsophageal needs by a good margin.

Since the receptive relaxation of the stomach is a reflex mediated through the vagus nerves as a result of the act of swallowing, it is different from the adaptation of gastric capacity to increasing contents, which Kelling has described;⁹ and it is also different from the relaxation of the cardiac end of the excised stomach, reported by Sick and Tedesco.¹⁰ In both these instances intragastric pressure does not fall; it merely fails within wide limits to become markedly increased as more contents are introduced.

Through the kindness of Mr. A. L. Washburn, who had accustomed himself to the presence of a balloon in the cardiac end of his stomach and a tube in his œsophagus, we were enabled to test the receptive relaxation of the human stomach after deglutition. The record of intragastric pressure showed a distinct drop after each act of swallowing.

The relaxation which occurs in the stomach is probably restricted to the cardiac end. The cardiac sac is the part of the stomach that varies most in capacity as the stomach is filled and emptied; it is the part that in both Langley's and May's observations was made to relax by electrical stimulation of the vagus in the neck; and it is the part in which the recording balloon rested in the experiments here described.

SUMMARY.

If the gastric wall is in tonic contraction, it relaxes after an act of deglutition. Intragastric pressure then falls nearly to zero, and the capacity of the stomach is readily enlarged. The lowest point of intragastric pressure is reached at approximately the time when a bolus is delivered into the stomach by the œsophagus. After the relaxation, which requires about ten seconds for its full development, there is a rapid recovery of the former tonicity.

⁹ KELLING: *Zeitschrift für Biologie*, 1903, xliv, p. 234.

¹⁰ SICK and TEDESCO: *Deutsches Archiv für klinische Medizin*, 1907, xcii, p. 439.

Repeated swallowing causes continued inhibition of gastric tonus.

This receptive relaxation of the stomach is probably confined to the cardiac end. It is an instance of reciprocal innervation of antagonistic muscles, and is controlled reflexly by the vagus nerves.

THE UNIVERSITY PRESS, CAMBRIDGE, U.S. A.